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Artificial Seeding

December 12, 1938

ARTIFICIAL SEEDING OF TREE SPECIES IN THE INTERMOUNTAIN REGION

By

T. E. MAKI, Associate Forester,
Intermountain Forest and Range Experiment Station,
U. S. Forest Service,
Ogden, Utah.

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Intermountain Forest and Range Experiment Station

Introduction

Artificial, or so-called direct seeding, of timber species was first undertaken in the Intermountain region almost three decades ago, and conducted thereafter for several years on a sizeable scale. After the first wave of enthusiasm had waned, sporadic attempts were continued here and there by investigative men, or by rangers and supervisors until the early twenties and in a few instances up to the present day. By 1925 Korstian and Baker (4) flatly admitted that artificial seeding had failed and could not be employed in the future regeneration programs in this region.

Viewed in retrospect these early trials at first thought might appear an adequate demonstration of the futility of the method; after all, they were cloaked in the convincing grandeur of size and seasonal "replications." On second and more critical thought, however, they lose weight as experimental evidence because of the haphazard and promiscuous manner in which they were carried out. Today there are numerous individuals who do not feel convinced that the early failures were sufficiently conclusive to warrant casting the method into discard without additional testing. The possibility that artificial seeding might be developed into a potent tool of regeneration still has a strong appeal.

It is the purpose of this report (1) to review some of the early work, (2) to describe and report the results of recent exploratory experiments in central Idaho, (3) to discuss and analyze the feasibility of the method, and (4) to indicate plans and prospects for the future.

Review of Past Work

There are but a few specific references to early work in this region. The Uinta and Minidoka seedings are described in some detail (1) (4). Other results might possibly be found in various progress reports in forest supervisors' office files, etc., but no attempt has been made to unearth them at this time. However, it should be interesting and worth while to review results of work in other western states outside the region in order to obtain a general picture of the scope of the trials, the estimates of costs (which under modern conditions probably signify little, if anything), and some indications of the factors accounting for success or failure.

Murdock (6) reported that on the Custer Peak experimental area 28 acres were sown broadcast and 12 acres sown with corn planter, both seedings being made in late May 1905. The season was exceptionally wet; survival very good with best stands in heaviest sod! Seedings in 1906 were poor; in 1907, good; in 1908, poor. In 1909, six hundred and fifty acres were broadcast sown, resulting in a catch of 100 to 200 seedlings per acre. Rodents caused the heaviest losses. Cost of seeding varied with ground preparation, being $31.66 per acre for careful spots, $12.00 per acre for modified spots, $5.50 per acre for furrows, $1.50 to $3.80 per acre for corn planter, and $2.05 to $2.65 per acre for broadcast sowing at the rate of 4 pounds of seed per acre.

Cox (1) reported that in 1909 seeding plots were laid out on almost all of the western forests. Out of these, 11 were considered successful. Douglas fir, on the whole, gave best results. Lodgepole pine, Sitka spruce, and western red cedar succeeded only in very rare instances. According to Wahlenburg (7), in 1910 over 15,000 acres were sown to various species. Barely 6 percent of the seedlings resulting from this promiscuous scattering of seed was reported as surviving.

In the spring of 1911, Larsen and Smith (5) initiated a seeding study in the Black Hills. A ponderosa pine seeding on a bare south exposure of a 1910 burn produced seedlings in every seed spot. At the same time, a sowing on a north exposure of the same burn yielded fair results only in the case of the seed spots. This north exposure had a fairly dense sod cover as contrasted to the bare south aspect. Corn planter sowings failed completely, failure being blamed on sod, rodents, and drought.

In 1913 Willis (8) attempted to protect ponderosa pine seeds from rodents by (a) planting deep, (b) poisoning, (c) screening, and (d) spraying seeds with chemicals having obnoxious odors. Deep planting protected seeds from rodents, but prevented most of the seedlings from breaking through to the surface. Wholesale poisoning proved ineffective. Sowing seed in screen wire was not worth the cost.(?) Covering seed spots with tar roofing gave good protection. Complete protection was provided only by wire cones, but the method was considered too costly in view of the fact that the cones had not eliminated drought mortality. Obnoxious chemicals failed to offend the olfactory nerves of the various rodents. White-footed mice were particularly destructive, devouring large quantities of field-sown seed.

Of the numerous early studies, the work of Wahlenburg (7) stands out both as to thoroughness and method. He planted 343 seeding plots in the Northern Rocky Mountain Region, using 53 percent white pine, 36 percent ponderosa pine, and the remaining 11 percent Douglas fir, lodgepole pine, and Engelmann spruce. One hundred and one out of the 343 plots were broadcast, 153 were sown with corn planter, and 89 were seed spots. Only 9 broadcasting, 2 seed spot, and 9 corn planter attempts succeeded. The most successful of these was on the Lolo National Forest where outstanding survival was attributed to sowing immediately after a fire, poisoning seed with red lead plus scattering poisoned oats over the planting site, choosing a favorable site, and being blessed with a moist season. (What else does it take?) The cost was $6.31 per acre.

Experiments at the Priest River Station prior to 1916 led to the belief that broadcast and corn planter methods were both expensive and unreliable. Accordingly, during 6 successive years (between 1916 and 1921) Wahlenburg (7) carried out a series of experimental seedings near Haugan, Montana, employing seed spots only. These extensive seedings were made in well prepared spots, with 25 seed per spot. Ponderosa pine proved to be drought resistant but failed primarily because rodents readily destroyed its seed. Douglas fir seed suffered less than pine from rodent depredations before germination (which is natural in view of the difference in seed size) and showed the best survivial, 50 percent of spring-sown spots and 22 percent of fall-sown spots still having survivors 2 years after sowing. Engelmann spruce suffered severe rodent

losses. Western larch had survivors in 11 percent of fall-sown and 3 percent of spring-sown spots. In all the experiments carried through 1921, Douglas fir showed marked superiority. Applications of litter mulches and fungicides proved ineffective. Drought accounted for the greatest number of seedling deaths, but cutworms and frost heaving were also important causes in the order listed.

These early tests, climaxed by numerous failures, cannot at best be considered as encouraging. Nevertheless, a few lessons might be gleaned from them. There are indications that for comparatively heat resistant species like ponderosa pine, a bare mineral soil with competition from other vegetation at a minimum constituted a reasonably favorable site; that some means of protecting seed from rodents and birds was necessary to insure anything like a uniform success; and that where competition from a well-established ground cover was severe and rodents numerous, success came only during wet years and under a combination of conditions neither well defined nor fully understood.

Within the last decade experimentation in the field of seeding has been revived in many regions. Since practically none of the results of this work has been formally published, no reference will here be made to specific studies. Needless to say, the approach in this new work is somewhat different, the tests being on a much smaller scale, more carefully planned and better designed to tell something about the causes of failure and the factors of success. Also evident is a refreshing departure from the old philosophy that colored the justifications for seeding thirty years ago. The major emphasis in the early

days rested heavily on initial costs. The feeling seemed to pervade that seeding was not justified unless it could be more cheaply executed than planting. In many instances it was also tried out and expected to succeed on sites which were too difficult to plant. In recent tests the tendency is to lean the other way; that is, to feel that seeding has every right to be tried out even on the choicest sites and to involve costs as high as in planting. After all, there is no logical basis for assuming that seeding must proceed under certain handicaps; that it should cost only five dollars per acre when planting costs fifteen. In any comparison involving the two methods, the important and equitable points to consider are that the final costs when measured in terms of unit areas of successfully stocked land are substantially the same and that the objectives of the regeneration program have been as satisfactorily fulfilled in either case.

It is hoped that the foregoing remarks on the early work will serve to dispel any feeling that revival of artificial seeding, in this region at least, is an entirely superfluous effort. Of course, there is always the chance that no amount of additional experimentation will alter the conclusions of those pioneering efforts for the region as a whole. In central Idaho, however, the evidence gathered since 1935 points to the possibility of successful seeding of ponderosa pine on the granitic soils. The main features of these tests and the conditions associated with good and poor response are discussed in some detail in the paragraphs that follow.

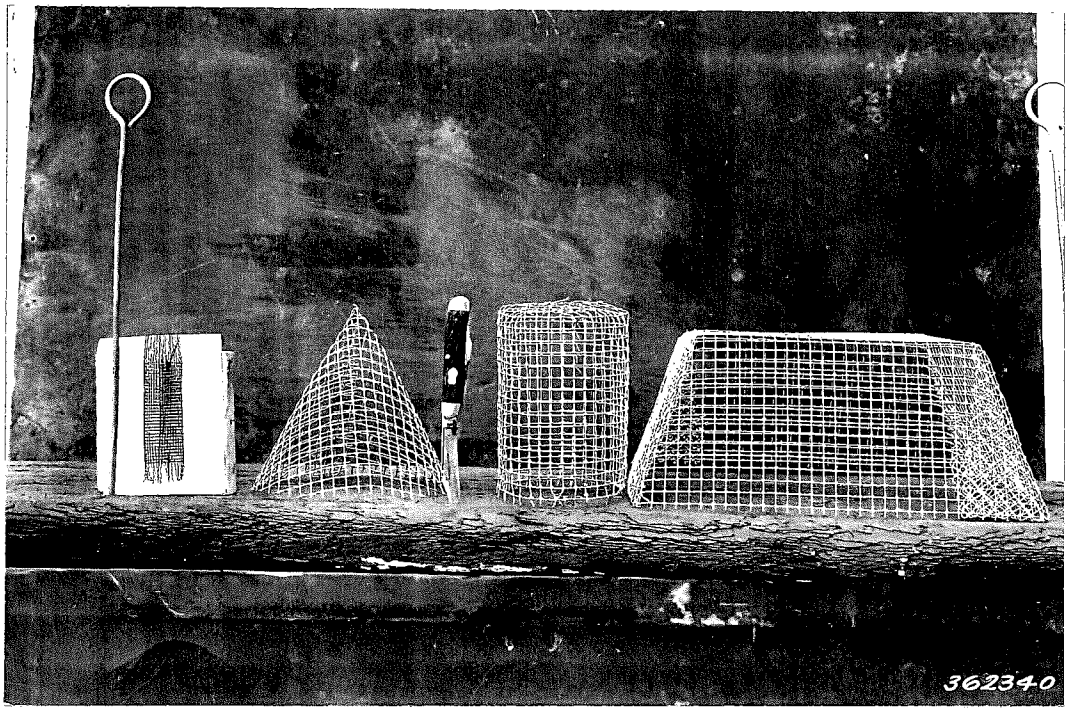
Outline of Recent Exploratory Studies in Central Idaho

Since November 1935, the Intermountain Station has conducted a number of exploratory seeding trials on ponderosa pine in the Boise Basin. Specifically these studies include:

1. A "paired spot" test using 1/2-inch mesh galvanized hardware cloth cages versus no protection, and involving a total of 540 spots sown in November 1935.
2. A test using 12-mesh window screen tubes versus no protection in "randomized block" arrangement involving 4 aspects, 3 separate locations, and 1,680 spots seeded first in October, 1936, and repeated in May 1937, and in October 1937.
3. A testing using (a) small 1/3-inch mesh hardware cloth cones, (b) 1/2-inch mesh hardware cloth cages, (c) 12-mesh window screen tubes, and (d) no protection. (See figure 1 for types of protection). Seeding made October 1937 on a fresh clean burn in a Latin Square involving 180 spots.
4. A test using (a) 1/3-inch mesh hardware cloth cones with no shade and with shade from shingle slabs; (b) 1/3-inch mesh hardware cloth cages with and without shingle slab shade, and (c) no protection. Seeding made in October 1937 in a 4 by 4 Latin Square on a 4-year-old brushed over burn, involving 320 spots.
5. A test using (a) 1/3-inch mesh hardware cloth cones with and without shade; (b) 1/3-inch mesh hardware cloth cages with and without shade; (c) 12-mesh window screen shade with and without shade, and (d) no protection. Seeding made October 1937 in a 6 by 6 Latin Square involving 720 spots.

Details and Preliminary Results of Exploratory Experiments

As indicated in the outline above, the first one of a series of informal exploratory seeding studies was initiated in November 1935. This consisted of series of paired spots in adjacent transects 5 feet apart, crossing several minor draws and ridges on the 1934 Elk Creek burn. Each spot consisted of a shallow dent made with the corner of a hoe blade. Five seeds were placed in each hole and covered to a depth of 3/4- to 1-inch with dirt firmly tamped over the seed. Snow from the first autumn storm still lay in patches over the seeding area, though most of the ground was bare. The surface soil froze hard every night, thawing out sufficiently during the day to permit seeding. The late seeding and the deep soil cover were effective in eliminating autumn losses of seed. As a matter of fact, rodents did not appear abundant on the area, owing at least in part to the severe fire (20,000 acres) that had ravaged this locality a year before. On May 9 of the following spring, just as the seeds were beginning to germinate, hardware cloth cages about $3\frac{1}{2}$ inches in diameter (like e in Figure 1 except 1/2-inch mesh and about 8 inches high) were placed over half of the spots. Later it was found necessary to drive a stake by each screen and to wire the cage to the stake to prevent the screen from being knocked over by cattle and sheep. (This is a very necessary precaution in heavily grazed areas and represents one of several disadvantages of wire cages.)



(a) (b) (c) (d) (e) (f)

Fig. 1. Types of devices used in ponderosa pine spot seeding in central Idaho. Reading left to right: (a) No. 9 wire pin used in pinning cones and cages to the ground; (b) 12-mesh japanned window screen tube; (c) 1/3-inch mesh 20-gauge galvanized hardware cloth cone; (d) ordinary jackknife (6 inches long when open, not used for protection, just included for scale); (e) 1/3-inch mesh hardware cloth cage or cylinder; (f) 1/3-inch mesh hardware cloth basket used in connection with a special competition study.

Inspections during the germination period revealed the folly of planting seed too deep, at least in soils on recent burns. While this practice had apparently afforded good protection against rodent and bird depredations, a very substantial percentage of the seedlings failed to emerge through topsoil layer which dried out rapidly and fairly early in the spring. There was a tendency toward cementation in the top layer of soil, doubtless accentuated by the comparatively large quantities of ash and carbon left on the surface from the recent fire. Examinations showed that seed germinated without difficulty, but could not break through, consequently dying below.

Intensive observations and records were kept only on the spots having seedlings that succeeded in breaking through, so the data in the following tables are based on these rather than on the total number of spots sown.

Table 1.- Rate of decrease in percentages[1] of successful[2] spots and total numbers of living seedlings during the first growing season. (Ponderosa pine seeding; November 1935, Elk Creek Burn.)

	Screened series[3]				
	May 9, 1936	June 3	July 10	Sept. 5	Oct. 31, 1936
	Percent	Percent	Percent	Percent	Percent
Spots	100	83.5	78.8	68.2	64.8
Seedlings	100	75.4	68.8	58.4	56.0
	Unprotected series[4]				
Spots	100	74.0	58.4	46.8	42.7
Seedlings	100	73.1	53.8	41.4	34.6

1/ Basis - total germination
2/ A spot with one or more living seedlings was termed "successful."
3/ Total germination equalled 48.7 percent) based on total number of
4/ Total germination equalled 43.3 percent) seed sown in successful spots.

It is evident that the screen cages are of some advantage but the superiority is not so great as one might expect. The comparatively small difference is due in part to scarcity of rodents on this burn and to the heavy toll taken by heat and drought in both screened and unscreened spots. Of the total numbers of seedlings that died in screened spots, 81 percent were attributed to heat and drought, 12 percent to trampling by cattle and sheep, and the remaining 7 percent to damping off. In the unprotected spots, only 57 percent were attributed to heat and drought, 14 percent to cattle trampling, and the remainder to rodents and birds. It is possible that the shading afforded by the screens is sufficient to encourage growth of damping-off organisms but the data from this study are too meager to be conclusive in this regard.

Table 2.- Rate of yearling decrease in percentages of successful spots and total number of living seedlings. (Elk Creek Burn ponderosa pine seeding, November 1935)

	October 1936	October 1937 1/	October 1938
	Screened series		
	Percent	Percent	Percent
Spots	64.8	56.6	56.6
Seedlings	56	45.3	43.8
	Unprotected series		
Spots	42.7	31.6	27.4
Seedlings	34.6	28.4	26.9

1/ Cages removed October 1937, i.e., at the end of the second growing season.

The advantage of screening is more apparent at the end of the third year than at the termination of the first growing season. This test does not tell what might have happened had the screens been removed in the autumn of 1936 instead of a year later. It is highly probable that protection for the first two growing seasons and possibly even through the second winter has some real advantages. In seeding as in planting, the mortality curve has a similar trend, plateau formation being evident after the second year.

Of interest and importance is the question regarding the rapidity of growth of the seedlings in these spots. It is natural to assume that development in spots without site preparation should be poorer than that of native seedlings in view of the crowding and competition between clumps of seedlings in all spots, in addition to actual mechanical interferences by the hardware cloth in protected spots. To obtain an indication of growth in both unprotected and screened spots, all seedlings were measured at the end of the third growing season.

Table 3.- Mean total height of 3-year-old seedlings in unprotected and screened spots. (Elk Creek Burn ponderosa pine seeding.)

	Mean height inches	Standard error of mean	Range of heights - inches
Screened spots	3.86	0.48	1.0 to 12.8
Unprotected spots	3.97	0.69	1.0 to 13.2
Mean difference	0.11		

The mean difference of 0.11 inches is not significant. No direct comparison is available between growth performance of seedlings in artificially sown spots and of natural seedlings. The seedlings in

these spots did not get started until May 1936, more than a year after the fire, and since no site preparation was attempted, competition, particularly from brush, was already severe. It must be admitted that their growth and appearance so far are poor. It is highly probable that in many instances seedlings in crowded spots need to be thinned in the second or third year in order to insure proper growth and development. Even without thinning, if this seeding had been made immediately after the fire much better growth might have been obtained as is indicated by the heights of natural seedlings which got started in nearby drainages from seed falling on the ash immediately following the fire. At the end of the fourth growing season these seedlings on good sites averaged nearly 13 inches in height, and on medium sites about 10½ inches. The comparatively rapid growth is attributed largely to the good start these seedlings got in the competition-free environment on the fresh burn. The fact that they represented a residual population surviving a severe process of selection is also doubtless a fairly important factor.

Test No. 2 was initiated in October 1936 with the idea of finding out whether the small japanned window screen tubes can be used effectively under central Idaho conditions. Seeding plots were laid out in three separate locations: (1) the station area near Idaho City; (2) the Elk Creek burn; and (3) the open grass-brush areas at the head of Bannock Creek. At each location plots were placed on (1) a ridge top, (2) a draw bottom, (3) a north slope, and (4) a south slope, with provisions

for 3 seasonal replications. Seeds were sown in unprepared spots in rows 6 feet apart, with the seed in half the spots protected by window screen tubes. Only 3 seeds were placed in each spot whether screened or unprotected. A total of 1,680 spots were under observation from each sowing, and the seedings were repeated in May 1937 and again in October 1937.

The first examination of the October 1936 seeding was made in June 1937. Although a surprisingly large number of seed had germinated in the unprotected spots, the protective value of the screens was already clearly evident. The tables below and discussion will serve to illustrate some of the differences.

Table 4.- Sources and components of variance in differences[1/] between numbers of "successful"[2/] spots per row (October 1936 ponderosa pine seeding plots).

Source of variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Between aspects	3	70.522	23.507	7.931°°
Between Location	2	21.500	10.750	3.627°
A x L	6	242.121	40.354	13.615°°
Error	72	213.429	2.964	
Total	83	547.572		

° Significant
°° Highly significant
1/ Screened spots minus unprotected spots - June 1937 count
2/ A spot was considered successful when at least one seed had germinated.

Table 5.- Mean number of "successful" spots per row[1/] in screened and unprotected rows. June 1937 count of October 1936 seeding.

	North Aspect		Ridge		Draw		South Aspect		Mean	
	Screened	Unprotected	Screened	Unprotected	Screened	Unprotected	Screened	Unprotected	Screened	Unprotected
Elk Creek	8.14	5.14	7.29	5.43	8.86	1.14	8.00	7.00	8.08	4.68
Station Area	8.14	4.14	7.43	3.43	8.43	3.71	7.86	2.14	7.96	3.36
Bannock Creek	6.00	4.57	8.57	3.29	6.14	2.71	8.43	1.71	7.28	3.07
Mean	7.43	4.62	7.76	4.05	7.81	2.52	8.10	3.62	7.77	3.70
Mean difference	2.81		3.71		5.29		4.48		4.07	

1/ Total of 10 spots per row.

The biggest differences occurred on the draw aspect, the smallest on the north. The small difference between north aspect screened and unscreened spots is not surprising; it is in concordance with measurements and observations in natural regeneration factor studies (2) and possibly reflects real relationships between feeding habits of rodents and vegetational development as affected by rate of snow recession on different aspects.

To determine whether total[1/] germination was significantly different by aspects or locations an analysis was made of the data from the June 1937 counts.

1/ Total germination percentage refers to ratio of total number of seedlings appearing to total number of seed planted in all spots (both successful and unsuccessful).

Table 6.- Sources and components of variance in total germination on protected seed spots. (October 1936 ponderosa pine seeding plots.)

Source of variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Between aspects	3	1,540.247	513.416	2.422
Between Locations	2	749.671	374.836	1.768
A x L	6	4,056.363	676,060	3.189°°
Error	72	15,261.799	211.969	
Total	83	21,608.180		

°° Highly significant

Table 7.- Total germination percentage in protected and unprotected spots (October 1936 ponderosa pine seeding plots).

Location	North Aspect		Ridge		Draw		South Aspect		Mean	
	Screened	Unprotected	Screened	Unprotected	Screened	Unprotected	Screened	Unprotected	Screened	Unprotected
Elk Creek	45.7	42.0	44.3	29.0	65.9	4.7	50.0	93.5	51.5	42.3
Station	53.2	47.6	54.3	53.0	49.5	29.7	40.7	15.7	49.4	36.4
Bannock	29.5	35.4	66.0	37.6	28.1	26.6	53.8	18.0	44.4	29.4
Mean	42.8	41.7	54.9	40.0	47.8	20.3	48.2	42.3	48.4	36.1
Difference	1.1		14.9		27.5		5.9		12.3	

Neither aspect nor location introduced significant differences in total germination. Interaction of these two is highly significant, however, for reasons not readily apparent. Differences within north aspects are again of low magnitude which substantiates previous observations.

From the foregoing tables and discussion it might be inferred that the screen tubes in general were quite effective, and a promising technique to employ in artificial seeding in central Idaho. This is an erroneous impression. To be sure, the tubes gave adequate protection to the seed and the seedlings insofar as rodent and bird depredations were concerned, but they did not and could not eliminate normal drought and heat losses. Quite the contrary, the black (japanned) screen tube appeared to induce high heat mortality. It is possible that they also induce excessive damping off. At the end of the first growing season only a few seedlings survived. Heat and drought had been apparently the chief causes of mortality, since actual counts showed that the numbers of seedlings present in the tubes in October were practically the same as in June. The first year survival figures are given in table 8.

Table 8.- Percentage[1/] of seedlings surviving at the end of the first growing season (October 1936 ponderosa pine seeding plots).

Location	North		Ridge		Draw		South	
	Screened	Unprotected	Screened	Unprotected	Screened	Unprotected	Screened	Unprotected
Elk Creek	4.2	26.1	0	0	5.7	0	0	3.1
Station Area	14.8	0	0	0	0	0	0	0
Bannock Creek	3.2	10.8	0	0	0	0	0	0
Mean	7.4	12.3	0	0	1.9	0	0	1.0

1/ Based on total germination

The May 1937 and October 1937 seedings employing the same technique as above showed equally poor results. The evidence is overwhelmingly against the use of this type of protection in central Idaho. In addition to inducing high heat losses and possibly also damping off, it has certain other serious disadvantages. For one thing, it is not sufficiently roomy to accommodate an adequate number of either seeds or seedlings to offset normal germination and heat and drought losses, nor does it appear to rust and fall to pieces under the dry climatic conditions of central Idaho as early as would be desirable, (though this latter shortcoming could be remedied possibly by acid treatment before sowing time.) Moreover, it is easily crushed by cattle and sheep and could not be employed where grazing use is being made of the seeded area.

As regards seasonal differences, fall sowings appear to be decidedly superior under ordinary conditions in central Idaho. In dry and normal years, spring sowings cannot be made early enough to obtain successful germination. For example, in the sowing made on May 1, 1937 no germination was obtained in the first growing season. What happened the following spring, however, was noteworthy and surprising. A very appreciable number of the seed germinated (as shown in table 9) indicating that viability of ponderosa seed remains on a high level even when subjected to the high surface soil temperatures that normally prevail throughout the summer.

Table 9.- Delayed germination percentage of ponderosa pine seed in screened and unprotected spots one year after sowing. (July 1938 count of May 1937 ponderosa pine seeding plots.)

	North		Ridge		Draw		South		Mean	
	Screened	Unprotected	Screened	Unprotected	Screened	Unprotected	Screened	Unprotected	Screened	Unprotected
Elk Creek	53.0	3.0	30.0	30.0	53.0	7.1	21.0	7.1	39.8	11.8
Station Area	33.0	1.4	60.0	36.0	29.0	0.0	37.0	10.0	39.5	12.2
Bannock Creek	26.0	61.0	23.0	57.0	5.7	10.0	8.5	14.0	15.8	35.8
Mean	37.0	22.0	37.0	41.0	29.2	5.7	22.6	10.3	31.6	19.9

Even after more than a year in the field the screens seem to have exercised a slight protective effect, but the results are quite variable, serving primarily as a measure of the magnitude of delayed germination or "hold-over" viability and as an interesting substantiation of what had been previously observed and noted in natural regeneration studies.

Other tests. The purpose of tests Nos. 3, 4, and 5 was to make a direct comparison of the protective value of hardware cloth cones and cylinders, and window screen tubes. In addition an attempt was made to find out effects of artificial shading by using cedar shingle slabs. The results of these tests are summarized in the follwoing tables:

Table 10.- Mean percentage of successful spots in sowings employing hardware cloth cones and cylinders, and window screen tubes. (October 1938 count of October 1937 ponderosa pine seeding plots.)

	Cones	Cones Shaded	Cylinders	Cylinders Shaded	Tubes	Tubes Shaded
	Percent	Percent	Percent	Percent	Percent	Percent
October 1937 West Bannock Burn South Aspect	100	-	13.3	-	10.0	-
July 1933 Pine Creek Burn Northeast Aspect	71.7	55.0	15.0	11.7	10.0	6.7
July 1933 Pine Creek Burn West Aspect	70.0	82.5	20.0	15.0	-	-
Mean of all cones	75.8					
Mean of all cylinders	15.0					
Mean of all tubes	8.9					

Cones were eminently successful. Cylinders and tubes were essentially failures. Shading showed no beneficial effects; if anything, it was harmful, but the net influence of the artificial shading was obscured by the presence of at least a small amount of natural shading from brush and weeds on all spots. It is possible that artificial shading (or any shade for that matter) in the early spring is actually harmful, but if put into effect after germination is complete would aid in minimizing heat kill. This point needs further investigation if it proves to be an important item.

The cylinders failed largely because the tops were not closed over entirely, about an inch hole being left after the top one-fourth of the cylinder sides were bashed inward (cf. #2 in Fig. 2). Apparently, this opening was sufficiently large to permit mice to enter. Some loss was also evident from frost heaving of both cones and cylinders, and subsequent failure of these to resettle solidly against the surface soil. This failure was accentuated by the practice of using two No. 9 wire pins to hold the cone or cylinder more firmly in place. Actually what happened was a tendency for the cones to remain suspended on the pins after being heaved clear of the surface. It is thought that loss from this source can be largely eliminated by not using these pins.

The perfect performance of cones on the West Bannock burn is due not only to the good protection afforded by cones but also to the practical absence of all competition. No site preparation was attempted on any of the seedings, but the recent fire on the West Bannock area was unquestionably a big help. On the other areas, brush and weed competition was relatively severe.

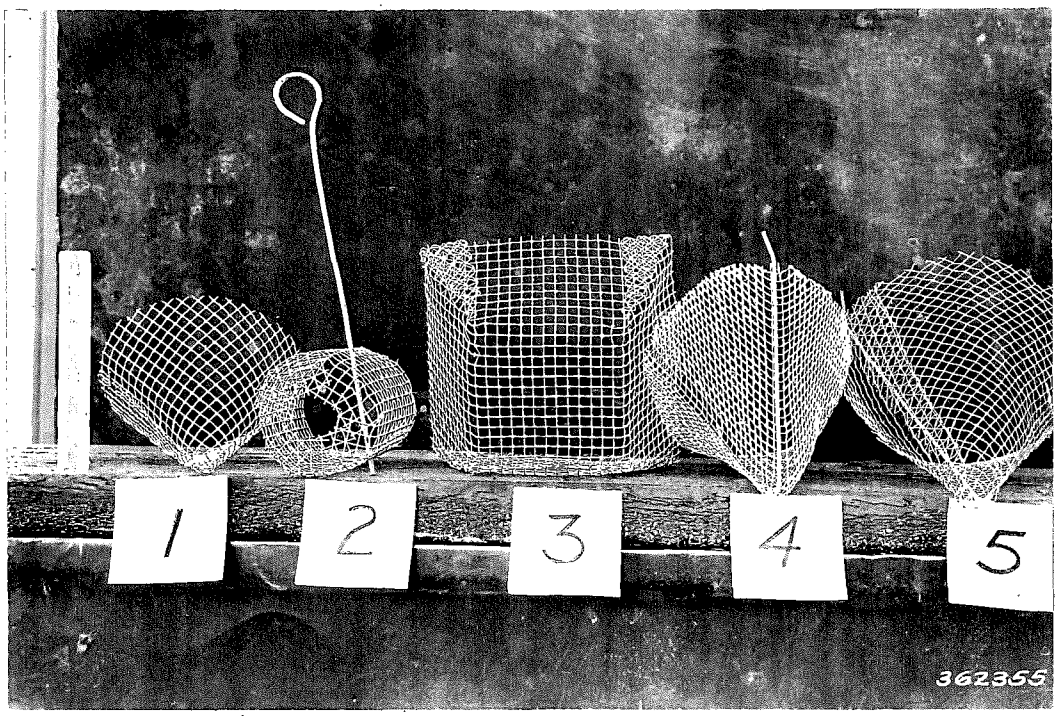


Fig. 2. Types of protectors used in ponderosa pine spot seeding in central Idaho. No. 1. 1/3-inch mesh 20-gage galvanized hardware cloth cones. No. 2. Cage of same material showing 1-inch opening in end; the failure of cages to provide protection was attributed to this opening which apparently permitted mice to enter. No. 3. A basket of same material, a larger "edition" of which was used in connection with plant competition plot seedings (see Fig. 1). No. 4. A "stamped" commercial product (one piece) furnished with 1/8-inch wire prongs and finished with a coating of hot prime spelter. No. 5. Same as No. 4 except rolled instead of stamped and finished in a coating of 75 percent tin and 25 percent lead with a covering of a seal coat. This covering is not quite so lasting and rust preventive as the hot galvanized coat in No. 4.

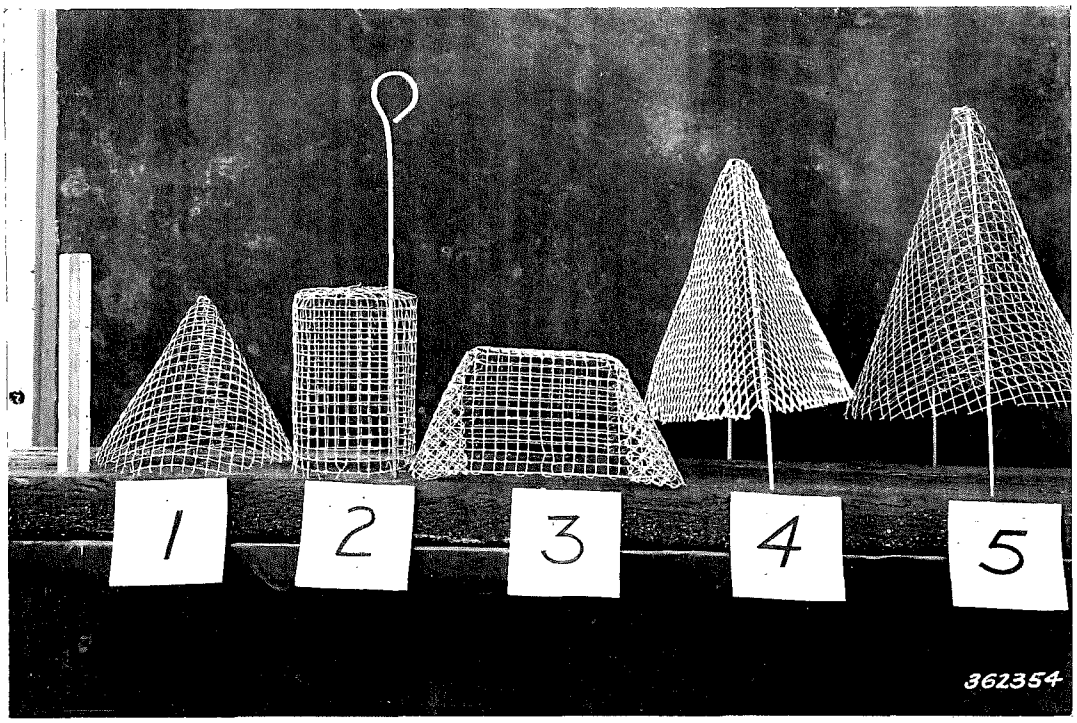


Fig. 3. Side view of the same items as shown in Fig. 2. No. 1 has given excellent protection against rodents. Its chief drawback is its small effective size (basal diameter $5\frac{1}{2}$ inches, height $5\frac{1}{2}$ to 6 inches). This is the smallest size suitable for ponderosa pine; in fact, under favorable growth conditions its apex does not have sufficient room for seedlings. The large cone referred to in the text is similar to No. 5 but without the prongs and with a basal diameter of $10\frac{1}{2}$ inches and a height of 11 inches instead of corresponding dimensions of 8 inches and 9 inches as in No. 5.

Lessons Learned from Exploratory Tests

These exploratory tests have aided very materially in focusing attention on the important and real problems that must be solved if artificial seeding is to succeed. Many of the results from such exiguous studies as these are necessarily more indicative than conclusive, but it is expected that additional experimentation will only confirm, not materially alter, the present indications.

For ponderosa pine on the granitic soils of central Idaho the following points are fairly well established:

1. That seed and young seedlings must be protected from rodents. Broadcasting or sowing in spots without protection is an appalling waste of seed except possibly when such seeding is done on large burns, well inward from the borders, and immediately (i.e. before brush growth begins) after the fire.
2. That competition from brush, grass, and weeds must be reduced by some means or another. Sowing immediately after a fire (cf. Fig. 4) offers a partial solution but on old brushed-over burns some means must be found to reduce competition (cf. Fig. 5). Skid trails, burned brush pile sites, etc., on cut-over areas offer good seeding chances. Release cuttings or weedings may be necessary during the early years.
3. That fall sowing is better than spring sowing if complete protection is provided. Ordinarily untreated seed cannot be sown early enough in the spring in central Idaho to obtain satisfactory germination. Unless seed can be treated to

Fig. 4. View of a small drainage on the August 1931 Quartzburg burn, Boise Basin, Idaho. Photo taken May 9, 1932 before brush and weeds started growth. Sites like these are ideal for seeding and planting for the reason that competition is at a minimum. While falling snags and limbs may cause appreciable injury to seedlings it is better to sow or plant while the ground is bare than to wait for pre-planting treatment or natural disintegration of snags, since such waiting would mean a tremendous increase in vegetative competition.

Fig. 5. View of same drainage as shown in Fig. 4 but from a different angle and three growing seasons later (Photo taken September 21, 1934). Vegetative competition from brush, grass, and weeds is already severe although heavy grazing and the cured or dead condition of the plants makes for a lighter appearance in its density in this picture. Reduction of competition on burns as old as this, or older, is a major problem to be solved before seeding can be expected to yield good results. Planting would ordinarily seem the preferable method if vegetative competition cannot be feasibly and adequately reduced.

induce very rapid germination, fall-sown seed will enjoy a big advantage over spring-sown seed. Fall-sown seed must be well protected because of the long period of exposure of seed to predators.

4. That small window screen tubes are not satisfactory. Heat kill under central Idaho conditions is tremendous. Enlarging screens introduces problem of excluding rodents. The shade from such fine mesh may also be excessive and detrimental for several reasons.

5. That hardware cloth cylinders or cages are not recommended. Closing ends of cages is a big job; leaving holes in top allows rodents to enter. Cylinders have the additional disadvantages that they are readily knocked over, and do not nest, hence are too bulky for packing to the field and back.

6. That 1/3-inch (3 x 3) mesh hardware cloth cones furnish sufficient protection against ordinary rodents and birds of central Idaho. One-half-inch mesh cloth is too coarse, allowing small mice to enter; 4 x 4 mesh would furnish more shade (to reduce heat kill) but costs more. These two cloths need direct testing to determine whether material advantages accrue from the finer mesh, higher priced cloth; the extra shade may be actually harmful. Cones have the advantage of nesting--a real asset in packing, storing, and transportation.

7. That young seedlings must be protected until stems are definitely suberized. At this rate, cones should be left on at least until about the middle of August in the first growing season. Retain-

ing the cone protection through the first winter or even through the second growing season may be worth while.

8. That grazing must be excluded during the first few years. It is essential to the success of the seeding that sheep grazing be excluded during initial establishment; and it is also necessary either to exclude or to restrict the numbers of cattle during the same period. Injury from grazing by livestock takes many forms: knocking over cone protection; trampling cones, trampling and browsing seedlings, etc. The idea that grazing is helpful because it reduces competition from lesser vegetation is without real foundation. Grazing to be effective would have to be so severe as to be ruinous from other standpoints. In other words, it would have to be of an intensity obtained only on sheep driveways, which indeed might be utilized to advantage on certain occasions and under certain conditions.

9. That only about 50 percent of clean and sound ponderosa pine seed can be expected to germinate under the natural conditions encountered in seeding. Adequate allowance must be made for germination failures which are fairly constant, and for drought and heat losses which are as yet largely unpredictable. Fifteen seeds per spot is suggested as a conservative number.

A Brief Description of New Studies

The exploratory tests cited above have largely been abandoned, but two new studies have been initiated in the Boise Basin. Both of the new studies are fairly comprehensive. The first of these involves a test of seeding only; the second involves both seeding and planting.

Test No. 1. This test is a fall sowing of ponderosa pine in 9 separate major or minor drainages representing a good cross-section of conditions encountered in the Boise Basin. Variables in this test are cone size, degree of scalping, and time of removal of cones. The two cone sizes are: (1) the small type (No. 1 in Fig. 3) with about a $5\frac{1}{2}$-inch basal diameter and height of about $5\frac{1}{2}$ inches. This size is considered the smallest suitable for ponderosa pine. Even this size tends to cause some crowding, but the effects do not appear particularly harmful as yet; (2) the large type with about a $10\frac{1}{2}$-inch basal diameter and height of about 11 inches. This size is considered about the largest suitable for ponderosa pine or for any other species for that matter because of weight and cost. It has an ample basal area, affording some spreading of seed at sowing time and also enough height to allow leaving it on for at least two growing seasons without crowding the center seedlings. Somewhere between these two limits there is perhaps a cone size optimum from the standpoint of weight, cost, roominess, and general utility.

Degree of scalping. Three degrees of scalping comprise:

(a) No treatment

(b) Scalps 12 inches by 12 inches by 4 inches deep

(c) Scalps 30 inches by 30 inches by 6 inches deep

This is intended to show whether any reasonable amount of scalping is helpful. It is possible that local scalping is futile, and that aside from burning, nothing less than fairly drastic contour furrowing is effective in reducing competition sufficiently to affect seedling survival and growth.

Time of removal of cones. Six different dates of removal are scheduled in this test. They are:

1. Immediately
2. In the spring after snow melts
3. In June after germination is complete
4. In August after stems are definitely "suberized"
5. In October of first growing season
6. In October of second growing season

Information from the different removal dates is expected to give a fairly thorough insight into rodent and bird activity and may be helpful in devising cheaper methods of protection.

The design of the experiment is such as to validate the following analysis of variance. Blocks are split and cone sizes assigned at random to each half, with scalping and time of removal randomized by rows within each half.

Sources and components of variance are given in the table below:

Source of variation	Degrees of Freedom	Sum of Squares	Mean Square
Cone size	1		
Size x Location (Error)	7		
Total major treatments	8		
Degree of Scalping	2		
Time of Removal	5		
DS x TR	10		
DS x S	2		
TR x S	5		
DS x TR x S	10		
DS x S x L	14		
TR x S x L	35		
TR x DS x S x L (Error)	70		
Total	161		

Test No. 2. This test involves direct comparisons between spot seeding with two types of protection and planting of seedbed nursery stock. The complete list of variables are given below:

1. Ponderosa pine fall seeding with large cones
2. Ponderosa pine spring seeding with large cones
3. Ponderosa pine fall seeding with AAA netting cover
4. Ponderosa pine spring seeding with AAA netting cover
5. Ponderosa pine fall planting - Bannock Creek Nursery 3-0 stock
6. Ponderosa pine spring planting - Bannock Creek Nursery 3-0 stock

The test further involves the same 3 degrees of scalping as used in Test No. 1. The AAA netting is being tried out because of the relatively high order of protection exhibited by it in nursery seed beds. The spring seeding in this test will employ pretreated seed to hasten germination. Untreated seed is already known to fail in spring sowing (except possibly in very wet years). Seed and seedlings are sown in blocks in 3 major drainages. Treatments are randomized by rows which are 8 feet apart and spots 5 feet apart in rows, 15 spots per row. Treatments are replicated twice in each block, at random of course, to serve as a measure of error.

Provided the variances are essentially equal in magnitude the following method of analysis can be applied to this experiment.

Source of variance	Degrees of Freedom	Sum of Squares	Mean Square
Method of Regeneration	5		
Degree of Scalping	2		
Location	2		
MR x DS	10		
MR x L	10		
DS x L	4		
MR x DS x L	20		
Error	54		
Total	107		

It is intended to replicate both tests No. 1 and No. 2 over a period of two or three years to obtain an indication of the influence of climatic fluctuations. Minor modifications of the present scheme may be made if experience shows this to be desirable.

A Rough Comparison of Seeding and Planting Costs

The strong appeal of artificial seeding in the past has rested primarily on the assumption that seeding is cheaper than planting. Most of the early work proceeded on this premise (and, it is believed, failed largely because of it). The recent exploratory studies indicate that this premise is false at least as regards initial seeding costs under central Idaho conditions. Equitable comparisons of seeding and planting methods are not yet available so the question of final establishment costs is largely a matter of conjecture. Fairly good estimates of initial costs already have been obtained, however, and these may indeed yield useful clues as to the final outcome. In the preliminary analysis that follows, the comparisons will attempt to show, first, cost differences in seeding when two sizes of hardware cloth cones are employed, and second, cost differences between seeding and planting. It is hardly necessary to point out that this sort of an analysis is somewhat biased in that it involves only two types of protectors (cf. Nos. 1 and 5 in Fig. 3) which have furnished good protection under central Idaho conditions but which represent relatively crude and costly devices from a very limited number of types that have been tried out to date. The comparison does not, therefore, involve seeding in a broad way, but only seeding with the aid of hardware cloth cones.

In using hardware cloth cones for seeding, the first item to consider is the cost of materials and cost of labor to manufacture the cones. Offhand, it might appear that cones could be most cheaply made by any one of various wire cloth, fence, or steel products manufacturers, and the finished product ordered direct from them. Several inquiries have

indicated that this is not apparently the case. Most manufacturers are not in a position to begin immediate production of the items, and for the small present demand they tend to set the price too high, ranging all the way from about 12 cents per item for a product like No. 1 in Fig. 3 to 25 cents for items like Nos. 4 and 5 in the same picture. Without the 1/8-inch wire prongs these last two would be a few cents cheaper. The large cone referred to in this study has a 10½-inch basal diameter and an 11-inch height as contrasted to an 8-inch diameter and a 9-inch height for cone No. 5 in Fig. 3. Without prongs[1/] this cone would cost not less than 25 cents if ordered ready-made. With one exception the various reports and quotations from firms and stations place the per item cost considerably above that expended on "home and hand" made products employing CCC labor for manufacture. The one exception is reported from an eastern experiment station which indicates that a St. Paul concern stamped out a product about the size of No. 1 in Fig. 3 for about 3 cents each.

The time figures and material costs in this are based on data obtained during hand manufacture of a total of about 5,000 cones by unskilled CCC labor. Table 11 presents a summary of material and labor costs per cone and per thousand cones.

1/ The prongs, as was pointed out earlier, are actually a nuisance in localities where soils are subject to frost heaving because they tend to keep the cone suspended after heaving has occurred; accordingly the use of prongs or pins to hold down cones need not be considered further.

Table 11.- Material and labor costs in manufacturing large and small 1/3-inch mesh, 20-gage hardware cloth cones.

	Large Cones[1]		Small Cones[2]	
	Per Cone	Per Thousand	Per Cone	Per Thousand
Material[3]	$.053	$53.00	$.0176	$17.60
Labor	.0122	12.20	.0121	12.10
Total	.0652	65.20	.0297	29.70

1/ Basal diameter 10½ inches, height 11 inches
2/ Basal diameter 5½ inches, height 6 inches
3/ F.O.B. Boise, Idaho

In one sense the labor costs are conservative since they are based on the CCC wage scale of $1.50 per 7-hour day. In this case the unskilled CCC labor was actually used so the picture is real. Other factors tend to liberalize the allowance made therefor. After the initial training the work was done without strict supervision so the output was perhaps not so efficient as could be expected on a fully supervised job. A small crew was used which tended to raise supervision costs abnormally. All work, such as cutting, rolling, etc., was done by hand, whereas relatively simple machinery could be made which would increase rate of production manifoldly for the various stages. In material costs some reduction might also be realized through quantity purchases. The net result is that the costs quoted here are liberal.

Interest naturally centers on the actual seeding costs rather than cost of cones alone. Fairly reliable estimates indicate that 1 man can establish 650 spots per 7-hour day or 1,000 spots in 11 hours.

Using CCC boys the labor cost for establishment would amount to $2.36 per 1,000 spots. But in seeding with wire cloth cones an item of considerable importance enters the picture. The cones must be gathered up one or two years after the seeding since for one thing they do not disintegrate and hence interfere with seedling development, and for another and more important reason, the initial cost of the cones is so high that several seedings are needed to reduce depreciation to a reasonable figure. Judging by the performance of this type of cones in initial tests, eight seedings appear to constitute a conservative depreciation period. The cones should hold up actually for a considerably longer time, but since some losses are inevitable and repairs may be necessary in the interim, it is well to discount the gross expectancy period by a substantial figure. A good guess at cost of pick-up service on central Idaho planting chances is $2.50 per 1,000 cones, including pack horse hire.

Assuming 1,000 spots per acre to be a reasonable intensity of sowing ponderosa pine in central Idaho (using about 15 seeds per spot) the elements making up the per acre cost of the operation can now be summarized as follows:

Table 12.- Per acre cost of artificial seeding of ponderosa pine in central Idaho, employing large or small wire cloth cones.

	Large Cones	Small Cones
Total cost of 1,000 cones	$ 65.20	$ 29.70
Cost of 1,000 cones when total cost is prorated over 8 service periods	8.15	3.72
Labor for sowing	2.36	2.36
Seed (2 pounds at 75¢ per pound)	1.50	1.50
Pack horse hire for sowing	1.00	1.00
Pick-up service after sowing	2.50	2.50
Total cost per acre	$ 15.51	$ 11.08

The total cost does not include supervision of seeding nor transportation to planting area. These items are so variable (depending largely on crew size and distance) that no estimates will be attempted here. They would in no case materially affect comparisons between cone sizes nor those between seeding and planting methods.

Seeding costs by themselves do not tell the whole story of the financial advantages or drawbacks of the method. Comparisons with planting under similar conditions are necessary for evaluation of true differences. Rough figures for determination of initial cost differences are available again in this instance from experiments conducted in central Idaho. In a test of tool efficiency it was found that the average time requirement for planting 1,000 seedlings with a mattock (which is the principal implement currently in use in central Idaho) was 4.5 man-days. This figure refers to CCC 7-hour man-days which includes travel time and is therefore directly comparable with the estimate of 650 seed spots per 7-hour man-day quoted in a preceding paragraph.

The elements of cost in planting nursery stock include in addition to cost of stock, cost of planting, often also cost of heeling in planting stock, cost of transportation, and supervision. The last three items are omitted because of variability, the last two again being essentially the same as in seeding. Summarized for two age classes of stock the costs are as follows:

Table 13.- Per acre cost of planting 2-0 and 2-1 ponderosa pine by the mattock center-hole method in central Idaho.

	Age of Stock	
	2-0	2-1
Cost of 1,000 seedlings[1/]	$ 3.90	$ 7.67
Cost of planting 1,000 seedlings[2/]	6.75	6.75
Total	$10.65	$14.42

1/ F.O.B. Boise, Idaho
2/ Planting costs computed on the basis of $1.50 per man-day

It is seen that these cost figures even though sketchy, indicate no great spread between initial expenditures. The large cone costs are roughly comparable to those of 2-1 stock; the small cones to that of 2-0 seedlings.

Two or three other factors should be considered to make the comparison of initial advantages complete. These are weight and bulk of cones as compared to weight and bulk of seedlings. Table 14 indicates the magnitude of these values.

Table 14.- A comparison of weight and gross volume of 1,000 cones and 1,000 2-0 ponderosa pine seedlings.

	2-0 Seedlings	Small Cones	Large Cones
Total weight in pounds	45[1/]	120	360
Dimensions in inches	12" x 12" x 12"	28" x 32" x 18"	54" x 48" x 22"

1/ Includes weight of burlap cover and moist shingle tow packing.

The allowances for cone bulk are liberal. Economy in spacing could be effected possibly by different arrangement of cones; in this case it consisted of nested piles of 50 each set side by side. It is evident that in order to transport the cones in the field some sort of a semicollapsible basket or rack on the pack horse would be necessary; it is also evident from the weight and volume figures that the large cones referred to in this study represent the very maximum size that can be practicably handled in the field. To the cone weights should be added 2 pounds per 1,000 to allow for seed; to the seedling weights should be added planting tray weights, additional necessary packing, etc., to make the picture complete.

The above data and analysis afford a sketchy picture of the main initial cost elements of the two methods of regeneration. They still leave the big question of final costs unanswered. In the ultimate analysis that is the important thing. The impression one gains from this comparison is that planting stock enjoys some advantage over large cones at least, and primarily because of the weight and bulk differences and the need of other than manpower for distribution and pick-up service in the case of cones. When weighed in the light of relative degree of success in final restocking, this advantage may entirely evaporate. Experience and observation in central Idaho would make the following prognostication seem conservative and fair: that on unprepared brushed-over sites one could expect to find about 60 percent of seed spots surviving 2 years after sowing; only about 25 to 30 percent of the ordinary nursery seedlings at the end of a like period; and further that the distribution of the latter would be less favorable. The growth and ultimate

development of the surviving planted stock might be, however, much better. It is thus difficult to attempt a fair and complete evaluation until adequate experimentation has actually shown what the final outcome is going to be. Until such a time it is perhaps better that no further comparisons be attempted on so meager a factual basis as in the present case.

Future Prospects

The severe setbacks suffered from the plunging tactics of the first attempts some three decades ago resulted in more or less complete stagnation of thought and effort in the field of artificial seeding. This was an obvious but unfortunate outcome. Today there is so much that is still unknown and so little to show how to begin and which way to go. Progress has been intolerably delayed because the pioneering efforts were not cautiously and wisely executed.

The results from recent tests are encouraging but, owing to the limited scale, it is not at all certain that present indications are pointing directly to the most effective technique. Moreover, the specific conclusions from the recent work apply, so far as we know, only to ponderosa pine in central Idaho. Differences in soils, in amount and distribution of spring to fall precipitation, in types and numbers of rodent and bird populations, and in other factors may be so large from one part of the region to the next as to vitiate as yet any broad comparisons. Technique that succeeds on the coarse, acid, granitic soils of Idaho may fail completely on the heavy alkaline soils and comparatively abundant

rainfall of Utah. One thing appears certain already, namely, that for ponderosa pine in Central Idaho the successful way does not lie in the direction of promiscuous scattering of seed but rather in fewer seed more adequately hidden from rodents, and more fully protected from heat and drought during critical periods. One needs only to consider the arithmetic of Nature to realize what tremendous odds seed and seedlings have to overcome. For example, in the Pine Creek area of the Boise Basin, combined measurements and estimates by seed traps (3) indicated a mean seedfall of 307,000 per acre in selectively cut stands of ponderosa pine--a number equivalent to more than 36 pounds of seed! This amount of seed resulted in a mean germination of 5,052 seedlings per acre, of which only 558 seedlings survived at the end of the first year! Five hundred and fifty-eight 1-year-old seedlings per acre cannot be considered a satisfactory catch in central Idaho. Nature attempts to offset the effects of heat, drought, and predators by sheer force of numbers, but man cannot hope to, should not want to emulate such an egregious practice, such a gross technique. He must resort to craft and cunning, to skill and guile.

Numerous possibilities remain unplumbed. The tests described in this report represent rather crude, cumbersome, and costly methods. It is probable that seeding will always involve some costly features, (and also some "strong-arm" practices, particularly in the site preparation phases). But there are still the relatively unprobed avenues of fertilizing, of repellants, of pretreated or pregerminated seed, of local poisons, agar pellets, etc. Out of these alone or in various

combinations, with or without mechanical devices, may evolve a method that is feasible, economically and otherwise. Until all the possibilities have been exhausted it shouldnot be considered that in the Intermountain Region seeding has received a fair and adequate trial.

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